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Colorless Receiver Enabling Crossconnect Based Metro-Access Interfacing Nodes for Optically Labelled DQPSK Payload Signals

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Abstract - We experimentally demonstrate a colorless receiver for optically labelled DQPSK payload signals enabling crossconnect interfacing nodes between the metro and access network segments.

I. INTRODUCTION

In a packet switched network, payload signals may arrive from different destinations on different wavelengths to the same receiver [1]. Differential quadrature phase shift keying (DQPSK) modulation format is considered a promising candidate for robust and high capacity signal transmission [2]; however receivers employing a delay-and-add interferometer require a phase matched delay to each incoming wavelength. Performing phase matching of the demodulator on a packet by packet rate may prove a challenging task. Alternatively, allocation of a dedicated DQPSK demodulator for each wavelength may be used in the network, however it is a complex and cost ineffective approach. In this article we present an optical crossconnect (OXC) architecture for label-controlled DQPSK signals, employing a colorless multi-wavelength receiver. The receiver is based on phase preserving wavelength conversion to a common wavelength. We demonstrate its feasibility in an experiment with three WDM channels operating at 21.4 Gbit/s DQPSK signals with satisfactory performance when channels are received in an emulated packet arrival scenario.

II. METRO-ACCES CROSSCONNECT ARCHITECTURE

The foreseen introduction of wavelength division multiplexing passive optical networks (WDM PONs) with capacity of 10 Gb/s motivates us to propose the use of an OXC supporting both transparent payload routing (optical bypass of payload signals) and electronic signal termination capabilities for efficient metro-access interfaces. Figure 1 shows an illustration of an OXC that can serve as an interfacing and routing node between the metropolitan and access networks. Considering optically labelled DQPSK payload signals, packets with a local destination are directed to the DROP block of the crossconnect. Other packets will be optically by-passed and directed to the next node on the path to their destination. At the DROP block, optical packets are transformed into the electrical domain and forwarded to the data storage and processing (DS&P) block. This same block handles packets originating from the local access network to be directed to the ADD block for subsequent insertion into the metropolitan segment by the switching subsystem of the OXC. We will in the sequel focus on the colorless receiver that will allow the reception of multiwavelength DQPSK packets at the DROP block.

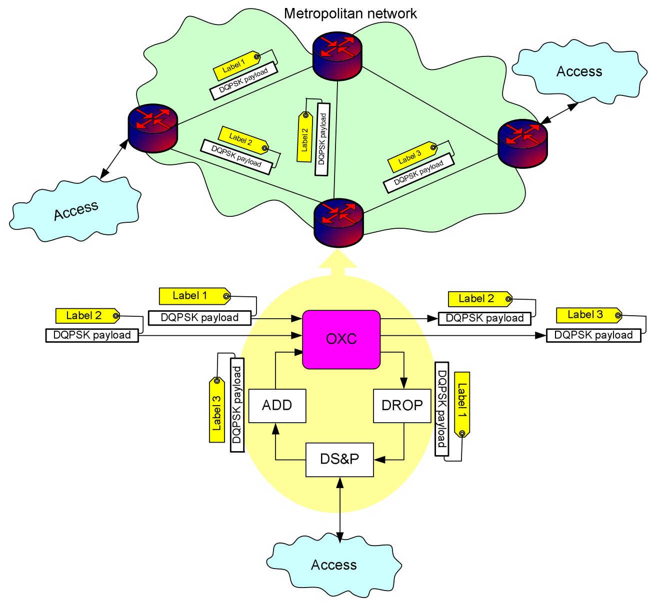

Figure 1: Metro-access interface scenario for DQPSK optically labelled packets.

III. COLORLESS DQPSK RECEIVER

Phase preserving wavelength conversion by four-wave mixing (FWM) is performed in a semiconductor optical amplifier (SOA). Conversion to a common wavelength of a number of different wavelength can be achieved by a pre-assigned arrangement of the pump wavelength as illustrated in Figure 2, for the case of three channels system. Moreover, it is also possible to re-use the pump signals simultaneously as transmission signal as shown in Figure 2 resulting in having two common receiver wavelengths $R_{1,2}$

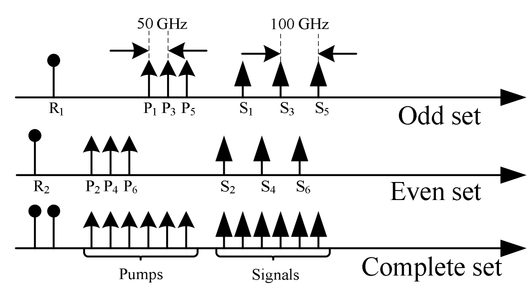

Figure 2. Experimental setup pump/signal allocation scheme in frequency domain.

IV. EXPERIMENTAL SETUP

A simplified block diagram of the experimental setup is shown in Figure 3. Continuous wave (CW) light from the three signal lasers was coupled into a Mach-Zehnder modulator (MZM) by polarization maintaining (PM) directional couplers. The MZM was driven by an electrical clock signal at the pulse rate of 10.7 GHz for pulse carving, and by a weak sinusoidal modulation at half the symbol rate (5.35 GHz) for optical packet labelling. After pulse-carving, 21.4 Gbit/s DQPSK modulation was applied by a parallel MZM superstructure. Modulator loss was compensated by an erbium doped fiber amplifier (EDFA). The 5.35 GHz labelling tone was detected by a photodiode and an electrical spectrum analyzer (ESA). This was done before the wavelength conversion, as the presence of the label would determine if the signal should be routed on in the network or if it should be send to the receiver.

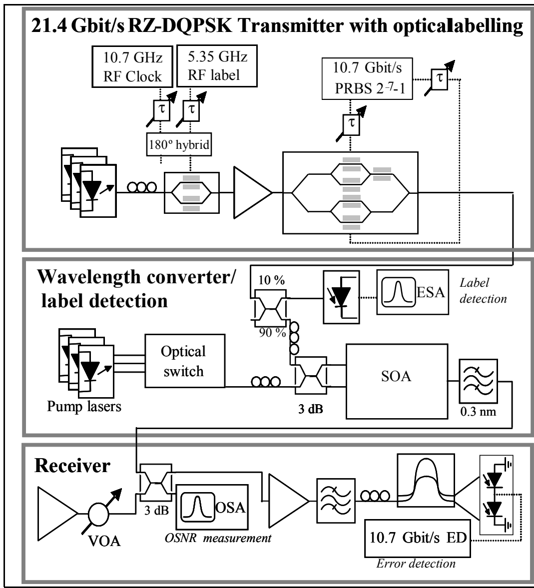

Figure 3: Experimental setup

A pump and signal wavelength arrangement as shown in Figure 2 was used around 1550 nm, within the gain bandwidth of the used SOA for wavelength conversion. Before detection, conversion to the receiver wavelength was performed by FWM in a SOA. Pump and signal powers at the input of the SOA were 12.0 dBm for the pump and 9.0 dBm for the signal. The signal was detected by a pre-amplified receiver setup, where amplified spontaneous emission noise generated by an open-ended EDFA was added to the signal in a 3-dB fiber coupler. One output from the 3-dB coupler was used for optical signal to noise ratio (OSNR) measurement by an optical spectrum analyzer (OSA), and the other output of the 3-dB coupler was used for data recovery by a one-symbol delay interferometer and a pair of balanced photodiodes. Bit error ratio (BER) was counted using an error detector programmed with the expected DQPSK tributary. In order to detect the two DQPSK tributaries simultaneously, two sets of delay interferometers and balanced photodiodes are required. In the laboratory implementation, the two tributaries were measured one at a time, and the total BER was calculated as the average of the two. The optical power spectrum analysis shows that the spectrum of the three channels turned out to look as expected: one of the FWM products being at the same wavelength for all three channels. The measured OSNR requirements for a BER of 10^{-9} was 26.0 dB, 25.3 dB and 24.3 dB for channels 1, 2 and 3 respectively, corresponding to OSNR penalties after wavelength conversion equal to 3.9 dB, 4.0 dB and 3.0 dB respectively. No measurable signal degradation was observed from the label. In order to emulate the scenario of packets from different channels arriving to the same receiver at different times, an experiment was carried out where the active signal and pump pair was cyclically switched through the three channels, and the BER was monitored without any tuning of the delay interferometer phase off-set or the center wavelength of the optical band-pass filter in the receiver. The OSNR into the receiver was kept at 23 dB. The results are plotted in Figure 4. The variations in BER turned out to be very small: BER between 2×10^{-7} and 3×10^{-8} was measured. No degradation was observed from the labelling tone, which proves the feasibility of implementation of the label control with DQPSK signals.

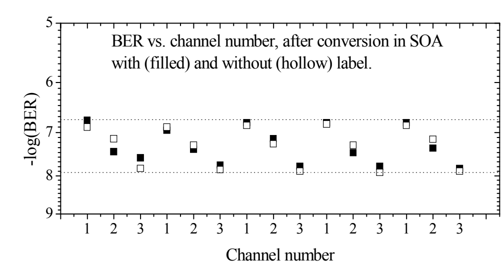

Figure 4. Monitored BER after a multiwavelength packet arrival scenario experiment.

V. CONCLUSION

This experiment has demonstrated the feasibility of the method of wavelength conversion of several channels to single wavelength as a way to overcome wavelength dependency of the DQPSK signal receivers in multichannel optical telecommunication systems.

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[2] N. Hanik, Electron. Lett., vol. 36, no. 17, pp. 1483–1484, 2004.